

SHEAR-INDUCED CONVERSION OF SEISMIC WAVES ON A FRACTURE

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RESEARCH OBJECTIVES

For geological and geotechnical applications, the behavior of fractures subjected to shear stress is of particular importance, particularly when frictional slip causes mechanical failure and changes in the hydraulic conductivity of the fracture. To monitor the changes in the stress acting on a fracture, seismic methods are among the most promising since the stress change causes changes in the stiffness of the fracture, which affects the transmission and reflection characteristics of the seismic waves. This research demonstrates how seismic waves can be used to measure the magnitude and direction of shear stress acting on fractures in rock.

APPROACH

Laboratory seismic wave transmission tests were performed on a single induced fracture in a granite core and in steel blocks with a periodic sawtooth surface that simulates a sheared fracture. Under a constant normal stress, the fractures were subjected to a range of static shear stress and the particle motion and amplitude of converted waves were measured. Numerical simulation was also performed using a 2-D dynamic boundary element method modeling a sheared fracture as an array of tilted open microcracks. Furthermore, an existing analytical model for the dynamic wave-fracture interaction (the seismic displacement discontinuity model) was extended to account for the dilation effect of a fracture under static shear stress.

ACCOMPLISHMENTS

The laboratory measurements showed the generation of mode converted waves (P to S and S to P waves) upon fractures subjected to static shear stress (see Figure 1). The amplitude of converted waves increased with the magnitude of static shear stress and the direction of particle motion changed in accordance with the direction of applied shear stress. These results are supported by the numerical simulations as well as the prediction by the analytical model. Using the extended seismic displacement-discontinuity model, anisotropic wave propagation in a multiply fractured medium subjected to static shear stress was also examined both analytically and numerically. The result indicated that the seismic anisotropy of the background medium can be strongly augmented by the shear-induced anisotropy of fractures.

SIGNIFICANCE

The experimental, numerical and theoretical results show that the static shear stress applied to compliant fractures alters the scattering characteristics of seismic waves. For normally incident seismic waves incident upon a single fracture, the amplitude and direction of particle motion of convert-

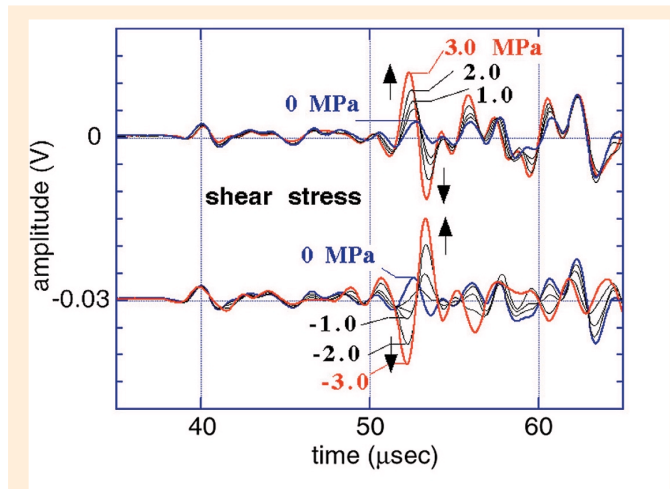


Figure 1. Conversion of incident S-waves to P-waves transmitted across a fracture. Amplitude of the converted wave increases with increasing static shear stress and the particle motion changes the phase by 180° when the direction of shear is reversed.

ed waves can be related to those of the static shear stress. For a medium containing multiple parallel fractures, higher-order anisotropy in the velocity and amplitude of waves result. The shear-induced conversion behavior of seismic waves has a potential as a stress-probing tool for not only geological and geotechnical applications but also manufacturing and material processing applications.

RELATED PUBLICATIONS

Nakagawa, S., K.T. Nihei and L.R. Myer, Shear induced conversion of seismic waves across single fractures, *Int. J. Rock Mech. Min. Sci. & Geomech. Abstr.*, 37(1-2), 203-218, 2000.

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